The Arctic Grayling, *Thymallus arcticus* (Pallas), in Providence Creek, Northwest Territories, 1976~79

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November 1982

Canadian Manuscript Report of Fisheries & Aquatic Sciences No. 1665

Canadian Manuscript Report of Fisheries and Aquatic Sciences

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Canadian Manuscript Report of
Fisheries and Aquatic Sciences 1665

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This is the 34th Manuscript Report
from the Western Region, Winnipeg

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Cat. no. Fs 97-4/1665 ISSN 0706-6473

Correct citation for this publication is:

Falk, M.R., M.M. Roberge, D.V. Gillman, and G. Low. 1982. The Arctic grayling, Thymallus arcticus (Pallas), in Providence Creek, Northwest Territories, 1976-79. Can. Manuscr. Rep. Fish. Aquat. Sci. 1665: vi + 27 p.

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ABSTRACT

Falk, M.R., M.M. Roberge, D.V. Gillman, and G. Low. 1982. The Arctic grayling, Thymallus arcticus (Pallas), in Providence Creek, Northwest Territories, 1976-79. Can. Manuscr. Rep. Fish. Aquat. Sci. 1665: vi + 27 p.

The spawning population of Arctic grayling in Providence Creek (local name; 61°15'N, 117°34'), Northwest Territories, was studied from 1976 to 1979. The study was initiated in response to local reports that fishing by illegal methods (snagging, snaring, etc.) and possible disturbance of spawning and/or spawning beds in recent years may have led to a decline in the size and number of grayling utilizing the creek. The study included tagging (1976-79) to determine movements and distribution of grayling, and a fish fence (weir) operation (1979) to determine population size and describe the biological characteristics of the spawning population.

Mean lengths from 382 to 395 mm, mean weights from 812 to 920 g and mean ages from 6.2 to 6.7 yr were characteristic of the spawning population. Male grayling appeared to grow faster and live longer than females. Annual mortality rates (fishing and natural) ranged from 0.50 to 0.80. Fecundity ranged from 6 475 to 16 887 ova/kg body weight (mean = 12 359 ova/kg body weight). Only mean age appeared to have declined from a previous investigation in 1966 but not substantially from 1976 to 1979.

Tag recapture information showed that grayling from Providence Creek exhibit a strong homing behavior with the majority of grayling spawning annually once sexual maturity is reached. Post spawning distribution extended along a 65 km stretch of the Mackenzie River. Distances travelled ranged from 2 to 72 km (mean = 45 km). Five tag returns (2%) external to the creek, indicated that Providence Creek grayling may contribute to sport fisheries in other areas.

The total spawning population of grayling in 1979 was estimated to be between 601 and 805 as compared to 1 000 fish in 1966. Of this total, a minimum of 130 grayling were taken by fishermen. In 1979, the upstream spawning migration extended from 17 May to 21 May at water temperatures of 5.0 to 8.7°C (peak on 18 May at 5.5°C). The downstream migration extended from 21 May to 26 May (peak on 22 May at 9.8°C). During the spawning period grayling are visible to fishermen but are generally not vulnerable to angling since they do not feed during this period. This non-biting by grayling was found to lead to angler frustration resulting in the use of illegal fishing methods.

Fishery management implications are discussed. As a result of this study and further observations in 1980, Providence Creek was closed to sport fishing during the period 15 April to 30 May from 1981 on in order to serve as a protected nursery area and to possibly augment recruitment to sport fisheries in the Mackenzie River (e.g. Providence Rapids, Kakisa River, Brabant Island etc.)

Key words: angling; closed waters; exploitation; fishery management; life history; movements; population structure; sport fishing; tagging; weirs.

RESUME

Falk, M.R., M.M. Roberge, D.V. Gillman, and G. Low. 1982. The Arctic grayling, Thymallus arcticus (Pallas), in Providence Creek, Northwest Territories, 1976-79. Can. Manuscr. Rep. Fish. Aquat. Sci. 1665: vi + 27 p.

La population d'ombres arctiques adultes (en âge de frayer) du Providence Creek (appellation locale; situé à 61°, 15' N et 117°, 34' dans les Territoires du Nord-Ouest) fit l'objet d'une étude de 1976 à 1979. Cette étude fut instituée à la suite de rapports provenant de la région voulant que l'utilisation de méthodes de pêche interdites (prise au hameçon par le corps, prise au collet, etc.) et une perturbation du frai et de la frayére aient réduit le nombre et la taille des ombres arctiques qui fréquentent le ruisseau. L'étude comprit l'étiquetage des ombres (1976 à 1979) pour en étudier les mouvements et la répartition, ainsi que l'aménagement d'une barriére (déversoir) (1979) pour déterminer l'importance de la population et décrire les caractéristiques biologiques des poissons adultes.

En moyenne, les ombres adultes mesuraient de 382 à 395 mm de longueur, pesaient de 812 à 920 g, et étaient âgés de 6.2 à 6.7 ans. Les ombres mâles semblaient croître plus rapidement et vivre plus longtemps que les femelles. Les taux de mortalité annuels (pêches et causes naturelles) se chiffraient entre 0.50 et 0.80. Les femelles portaient entre 6 475 et 16 887 oeufs par kilogramme du poids de leur corps (moyenne de 12 359 oeufs par kilogramme). Il semblerait que seul l'âge moyen des ombres ait diminué depuis une enquête menée en 1966, diminution qui s'est avérée minime entre 1976 et 1979.

Selon les données provenant de la prise de poissons étiquetés, les ombres du Providence Creek possédent un fort instinct d'orientation, car la plupart des poissons frayent chaque année une fois qu'ils ont atteint la maturité sexuelle. Aprés avoir frayé, les ombres voyagent entre 2 et 72 km (45 km en moyenne) pour occuper quelque 65 km du Mackenzie River. La prise de cinq poissons étiquetés (2%) à l'extérieur du ruisseau semble indiquer que les ombres du Providence Creek servent à la pêche sportive dans d'autres endroits.

En 1979, on estima la population d'ombres arctiques adultes à entre 601 et 805 poissons, comparativement à 1 000 individus en 1966. De ce nombre, les pêcheurs prirent au moins 130 poissons. En 1979, les ombres sont montés vers la frayére entre le 17 et le 21 mai, alors que la température de l'eau se situait entre 5° et 8.7°C (le point culminant de la migration eut lieu le 18 mai, par une température de 5.5°C). La descente s'est effectuée entre le 21 et le 26 mai (point culminant ayant lieu le 22 mai à

9.8°C). Pendant le frai, les pêcheurs peuvent voir les ombres mais ne réussissent généralement pas à les prendre à la ligne, car les poissons ne mordent pas. Il a été découvert que ce comportement frustrait les pêcheurs et les incitait à utiliser des méthodes de pêche interdites.

L'analyse porta également sur les effets de l'aménagement de la pêche. A la suite de cette étude et d'observations supplémentaires faites en 1980, on interdit toute pêche sportive sur le Providence Creek entre le 15 avril et le 30 mai à compter de 1981 afin d'en protéger les alevins qui serviront peut-être au recruitement des lieux de pêche sportive le long du Mackenzie River (par exemple: les Providence Rapids, la Kakisa River, le Brabant Island, etc.).

Mots-clés: pêche à ligne; lieu de pêche prohibé; exploitation; gestion de la pêche; cycle évolutif; mouvements; structure de la population; pêche sportive; étiquetage; barrage.

INTRODUCTION

Providence Creek (61°15'N, 117°34'W) is the name given by Bishop (1967) to an unnamed creek which enters the Mackenzie River 5 km upstream from Fort Providence, Northwest Territories (Fig. 1). The creek supports a spring spawning population of Arctic grayling, Thymallus arcticus (Pallas), which was first reported by Bishop (1967, 1971). Prior to 1975, the sport fishery on Providence Creek was limited to a few anglers from the Fort Providence - Hay River area. Occasionally, native people from Fort Providence would obtain fish from the creek for subsistence use (mainly dog food). Information obtained from long-term residents of the area and Fishery Officers stationed in Hay River indicated that fishing effort was sporadic and that the harvest of grayling rarely exceeded 100 fish annually. Since 1975, studies on grayling in the Kakisa River (Moshenko and Low, In prep.) and the Brabant Island area (Falk and Gillman 1974, 1980) has created an increased awareness of Arctic grayling and northern pike in Providence Creek and prompted an investigation on grayling in Providence Creek in order to identify their possible contribution to the sport fisheries in the Kakisa River, Brabant Island and other areas.

Studies have shown that over-fishing of grayling by anglers to be a major problem with most dramatic effects in areas that are readily accessible (Vincent 1962; Johnson 1971; Gerstung 1972). From general observations made by Department of Fisheries and Oceans (DFO) personnel it has been estimated that the number of anglers utilizing Providence Creek have increased over the years. Local reports indicated that excessive fishing for grayling in Providence Creek using illegal methods (snagging, snaring, spearing, etc.) may have led to a decline in their numbers which may possibly be reflected in other sport fisheries in the area.

This report presents biological information on the spawning population of Arctic grayling utilizing Providence Creek and their post-spawning distribution. Recommendations are made with respect to the long-term management of grayling in Providence Creek.

THE STUDY AREA

Providence Creek (Fig. 2) is typical of many small tributary streams draining spruce forest-muskeg areas along the Mackenzie River valley (Hatfield et al. 1972a,b.). The stream is at its highest flow in May but the flow is reduced to a trickle by late June, and, unless summer rains are heavy, is completely dry by fall. The water is characteristically tea-brown in color. Providence Creek originates in an undefined muskeg area and drains an area of about 100 km^2. The definable water course is approximately four km long, two to four m wide and less than one metre deep. In the upper three kilometres, the creek is blocked by a series of beaver dams. The streambed along this reach is composed of organic material with short sections of boulders. The lower kilometre of the creek is free of beaver dams and flows over boulders and coarse gravel. After passing through a timber culvert at the highway crossing, the streambed widens and includes deadfall and willow stands.

Arctic grayling ascend Providence Creek from the Mackenzie River in conjunction with the spring runoff as it cuts a channel through the ice of the creek. They normally spawn between the highway crossing and the first beaver dam but spawning has been observed as far up as the third beaver dam. Grayling leave the creek soon after spawning is over. Northern pike, Esox lucius (Linnaeus), are also present in the creek and are pursued by anglers.

THE FISHERY

In general, Providence Creek is utilized primarily as a food fishery. Most anglers using the Providence Creek are campers from the Kakisa River campground or workers from the immediate area who drive to the creek for an evening of fishing. Most angling for grayling usually occurs during the spawning period in the lower reach of the stream from below the highway crossing to the first beaver dam. Arctic grayling are not normally vulnerable to legal angling methods during spawning since they do not feed during this period (Bishop 1967, 1971). As a result many anglers, through frustration, pursue grayling using illegal fishing methods (snagging, snaring, spearing, etc.). This practice usually causes disruption of spawning grayling and forces them further upstream to a less suitable spawning habitat. Thus without proper management the fishery in Providence Creek and possibly in other areas may deteriorate.

MATERIALS AND METHODS

COLLECTION METHODS

In the spring of 1976 and 1978 grayling were dipnetted from pool areas in Providence Creek below the highway crossing (Fig. 2). High water flows through the culvert concentrating grayling at the downstream end thus facilitating their collection. After collection fish were held in plastic tubs, tagged and measured and then released upstream of the highway crossing.

In 1979, a fish fence was installed in the lower reach of the creek approximately 30 m below the highway crossing (Fig. 2) to enumerate the spawning population of grayling and to tag a portion of the migrants. Fence construction was completed 17 May and the trap remained in operation until 27 May when the project terminated. The fish fence was designed with a single trap (Appendix 1) to enumerate both upstream and downstream migrants.

Trap checks were scheduled at 4-hour intervals, however during periods of increased or reduced fish movement trap check frequency varied accordingly. During trap checks the entrance was closed and after examination the fish were released above or below the trap according to direction of movement. Species, number, tag recaptures and external blemishes were recorded. Tagging and live sampling was

completed as described in later sections. A number of small, immature grayling were observed within the vicinity of the trap; however their numbers were not recorded since they could pass through the fence openings.

TAGGING

Grayling collected by dipnet during 1976 and 1978 and from the 1979 trap operation were tagged with plastic spaghetti Floy tags. A Dennison tagging gun (Mark II) was used to insert the numbered tags into the left side of the fish near the posterior base of the dorsal fin. Personnel on site attempted to monitor the angler harvest of grayling and to obtain information on tag recaptures above the trap location. A two dollar reward was offered to anglers for the return of recapture information from tagged fish.

Tags on fish were readily visible within the creek, permitting observations on their movements within the stream and spawning behavior. Trap records of tagged fish were used to determine movements into and out of the spawning area, duration of spawning and population estimations. Tag returns from areas other than Providence Creek provided information on post-spawning dispersal and distances travelled.

CREEL CENSUS

In 1979, a partial creel census was conducted at Providence Creek during the operation of the fish fence. Information pertaining to the methods employed by creel census workers has been described by Falk et al. (1973), Falk and Gillman (1974) and Moshenko and Gillman (1978). As many anglers as possible were questioned as to the number of fish caught, released and retained by species as well as the hours spent fishing.

BIOLOGICAL SAMPLING

Biological information was obtained from sampling dead grayling (dead sampled) from trap mortalities and from sampling live (live sampled) grayling during tagging. Fork length (± 1 mm) and, when possible weight (± 20 g) were recorded. Scales from all fish sampled were removed from the left side of the fish above the lateral line and slightly forward of the dorsal fin and stored for later age determination. Sex and stage of maturity were recorded when possible for live fish from observations of extruded milt or eggs. As well, sex was determined by the size of dorsal fin as discussed by Bishop (1967, 1971). Maturity was determined for dead-sampled grayling by examination of the gonads and coded according to the scale described in Appendix 2. The stages were altered in 1979 only in order to account for fish which spawn in alternate years. The present system (1979 on) distinguishes between mature fish which will spawn in the current year (Stages 2, 3, 7 and 8) and mature fish which may spawn in the future but not in the current year (Stages 5 and 10). With the previous system it was difficult to distinguish immature fish (virgin) from mature non-spawning fish (non-virgin).

In 1976 ovaries were collected from 10 ripe female grayling. The weight of each ovary (±5 g) was recorded prior to wrapping in cheesecloth and preservation in Gilson's fluid for later fecundity determination.

LABORATORY PROCEDURES

Scales from grayling were later cleaned, placed between two glass slides and the annuli counted on the image (x60) produced by an Eberbach microprojector. Ages obtained from scale samples taken during tagging and subsequent recapture in Providence Creek were compared to assess the accuracy of the scale method. The scale method has been shown to be reliable for aging grayling from the study area (Falk and Gillman 1974). However recent investigations into aging techniques indicate some difficulty may be encountered for grayling aged as 9+ or older (Falk and Gillman 1980).

Fecundity was determined using the gravimetric method of estimation described by Healey and Nicol (1975). Ovarian tissue was removed from the egg mass and the remaining ova were brought to constant weight by air drying. A subsample of ova was counted and weighed and the total number of ova was determined by direct extrapolation. As tissue walls of the ovaries were severely ruptured in most samples ovum counts were performed for both ovaries combined.

DATA ANALYSIS

Biological data collected during the 1976-79 study were manipulated using an IBM 370/168 computer based at the University of Manitoba and a terminal located at the Freshwater Institute. The Statistical Analysis System (1972) was used to generate length, weight, age, sex and maturity summaries and to perform basic calculations. Some analyses were performed using a Hewlett-Packard programmable calculator (Model 9810-A). Total annual mortality rates were calculated using the methods outlined by Robson and Chapman (1961). Annual mortality rate is defined as the number of fish which will die during the year divided by the initial number (Ricker 1958).

Length-weight relationships were described by the following power equation:

$$\text{Log}_{10}W = a + b\ (\log_{10}L)$$

where: W = weight
L = fork length in millimetres
a = Y - intercept
b = slope of the regression line

The standard deviation of the coefficient $b(S_b)$ was also calculated.

Relative condition factors (K) were determined using the formula:

$$K = \frac{W \times 10^5}{L^3}$$

Tests of significance were made at P = 0.05 using the procedures outlined by Snedecor and Cochran (1968).

RESULTS AND DISCUSSION

HARVEST OF ARCTIC GRAYLING

In 1979, 19 (22%) of the anglers interviewed were successful. They caught and retained a total of 130 grayling and 13 pike during a total of 176 hours of angling. Catch rates for grayling were 1.5 fish per angler and 0.7 fish per angler-hour. It is believed from observations made that a portion of the retained catch of grayling was obtained by illegal methods and therefore the actual (total) catch of fish may not have been revealed to project personnel. As a result catch-effort information from Providence Creek cannot be compared to that reported elsewhere for the immediate area. Thus, the total harvest of grayling by anglers from Providence Creek must be considered as a minimum estimate.

LENGTH COMPOSITION

Mean lengths for tagged (Table 1) and dead-sampled (Table 2) grayling from Providence Creek in 1976 were combined for discussion purposes. The mean length of grayling for 1976 was 395 mm (N = 249) (Table 3) compared with 382 mm (N = 39) for 1978 (Table 4) and 390 mm (N = 133) for 1979 (Table 5). From information presented by Bishop (1967, 1971) the mean length of grayling was approximately 386 mm (modal length 390 mm) in 1966. Similarly, length-frequency distributions (Fig. 3) revealed only minor variations in size composition from 1976 to 1979 with the modal length remaining in the 380 to 400 mm group. It is evident from this analysis that the average size of Providence Creek grayling has not decreased despite reports of the fish possibly being heavily exploited in recent years.

In comparison to grayling in the immediate area of Providence Creek it is apparent that angled grayling from the Kakisa River in 1979 (Falk et al. 1980) and the Brabant Island area in 1978 (Falk and Gillman 1980) tend to be larger with the majority of fish exceeding 400 mm in length. Mean lengths of grayling from these areas are reported as 415 mm (mode = 400-409 mm) and 424 mm (mode = 440-449 mm), respectively. The larger size of angled grayling from the Kakisa River and the Brabant Island area is probably a result of a 356 mm minimum size limit. While no grayling greater than 450 mm were caught in Providence Creek in 1978 and 1979 fish in this size group were caught in 1966 and 1976 (Fig. 3). The disappearance of these larger grayling in recent years may be attributed to angling since this method has been shown to be effective in removing larger grayling from the population (Gillies 1975). However, the overall effect of fishing pressure on the Providence Creek grayling population from 1976 to 1979 does not, on the basis of size analysis, appear to have had a dramatic effect.

LENGTH-WEIGHT RELATIONSHIP

Length-weight relationship information for grayling from Providence Creek (1976 and 1978) is presented in Table 6. The differences in slopes and elevations of the length-weight regressions were not significantly different ($P = 0.05$) between sexes for 1976 or between years with sexes combined. Slopes of the regression lines (sexes combined) were similar to those reported from the Kakisa River ($b = 2.692$) (Falk et al. 1980) and the Brabant Island area ($b = 2.933$) (Falk and Gillman 1980).

AGE COMPOSITION

Mean ages for tagged (Table 7) and dead-sampled (Table 8) grayling from Providence Creek in 1976 were combined for discussion purposes. The mean age of grayling for 1976 was 6.7 yr (N = 224) (Table 9) compared with 6.2 yr (N = 38) for 1978 (Table 10) and 6.3 yr (N = 122) for 1979 (Table 11). Bishop (1967, 1971) indicated the mean age was approximately 7.5 yr (mode = 6 yr) in 1966. Comparison of age-frequency distributions (Fig. 4) revealed that, with the exception of 1979 the modal age has remained constant at age 6 from 1966 to 1978. The decrease in mean and modal age in 1979 appears to be due to a decline in ages 8 and 9 from 1966 and 1976 to 1979. While this may be attributed to the effects of exploitation it may also be a function of variations in year-class strength. Therefore on the basis of age analysis from 1976 to 1979 it is not possible to conclude that overfishing has led to a decline in abundance of older fish.

The mean and modal ages of Providence Creek grayling are lower than those from the Kakisa River (Falk et al. 1980) and the Brabant Island area (Falk and Gillman 1980). While recognizing the effect of the 356 mm minimum size limit the mean ages for these areas are reported as 7.0 yr (mode = 7 yr) and 6.4 yr (mode = 6 yr), respectively.

Grayling tagged in Providence Creek in 1976 and 1978 and recaptured during 1979 enabled a comparison of scale ages between 1976 and 1979 (Table 12). Agreement was excellent (100%) when there was one year between sampling but when there were three years between sampling the agreement was poor (22%). Grayling aged as 4 and 5 yr in 1976 were aged at 7 and 8 yr in 1979 with little difficulty. However, grayling aged as 6 to 8 in 1976 were underaged in 1979 with the extent of disagreement increasing with age. From this analysis it is concluded that the scale age for Providence Creek grayling is reliable up to about age 8 with a tendency to underage grayling from age 9 on. This problem is typical of the ageing using scales as discussed by Campbell and Babaluk (1979) and Erickson (1979).

GROWTH AND MORTALITY

Male grayling from Providence Creek grow slightly faster and live longer than females (Tables 7 to 9) but the difference in growth rates between sexes was not statistically different at $P = 0.05$. The average growth rate for Providence Creek grayling was slower than those reported for the Kakisa River and the Brabant Island area (Fig. 5).

Total annual mortality rates (A) for Providence Creek grayling (sexes combined), were

0.50, 0.80 and 0.61 for the 1976, 1978 and 1979 samples, respectively (Table 13). Mortality rates for angled grayling have been reported to be 0.53 for the Kakisa River (Falk et al. 1980) and 0.40 to 0.67 for the Brabant Island area (Falk and Gillman 1980). Actual mortality rates may be lower than those calculated because of the difficulty encountered in aging grayling age 9 and older.

FECUNDITY

Mean fecundity by weight for grayling from Providence Creek (length range: 373 to 432 mm) was determined to be 12 359 ova/kg body weight (range: 6 475 - 16 887 ova/kg body weight; N = 8). The mean number of ova per female was 11 229 (range: 4 694 - 15 867; N = 10). Fecundity for grayling from 1979 is similar to that reported previously by Bishop (1967, 1971) for Providence Creek (11 107 ova/kg body weight).

SPAWNING MIGRATION

Upstream

In 1979, the upstream migration of grayling into Providence Creek through the trap was first recorded on 17 May and continually monitored thereafter until 21 May when the upstream trap was closed (Table 15, Fig. 6). Some upstream movement was observed in the water flow under the ice but the major portion of the run occurred as soon as the creek was completely free of ice. As well, an unknown number of grayling were observed upstream prior to the installation of the fish fence. Water temperature on 17 May was 4.5°C (Table 16). The peak upstream movement through the trap occurred on 18 May at 5.5°C when 222 grayling were counted through the trap. Numbers of upstream migrants steadily decreased until only 7 were counted on 21 May when the upstream entrance of the trap was closed. In total, 467 grayling were counted moving upstream from 17 May to 21 May. Daily activity was greatest in the late evening and early morning with the majority of grayling moving into the trap between 2200 and 0400 hours (Table 16).

Downstream

The downstream migration of grayling began in the evening of 21 May and was continually monitored until 26 May (Table 15; Fig. 6). Peak downstream movement occurred on 22 May at 9.8°C when 227 grayling were counted through the trap. Daily activity appeared to be greatest at midday and midnight (Table 17). Downstream movements were not as regular as those encountered for the upstream run. A total of 471 grayling were counted through the downstream trap from 21 May to 26 May.

SPAWNING PERIOD

The 1979 spawning period for grayling in Providence Creek encompassed a four-day period from 19 May to 22 May in water temperatures ranging from 4.5 to 11.0°C (mean 8.1°C). Spawning was observed to take place between the highway crossing and the second major beaver dam (Fig. 7). The majority of spawning occurred over small rocks and gravel which are preferred substrates (Gillies 1975). However some spawning activity was noted in grassy areas and over organic substrates in the vicinity of beaver dams.

Spawning activity as described by Bishop (1967, 1971) was first observed on 19 May when water temperatures ranged from 4.5 to 9°C (mean 7.0°C). Peak activity occurred on 21 May at 7.0 to 10.0°C (mean = 8.7°C). Spawning activity decreased thereafter to 23 May when the majority of grayling had left the creek. From 58 tag recaptures in the downstream trap it was determined that the average duration in the spawning grounds was 4.2 days (range = 3-7) for both males and females.

MOVEMENTS

In 1979, observations on tagged and untagged grayling provided information on instream movements. The upstream movement was rapid and continuous. During this period most grayling appeared to move in pairs, and after reaching the spawning area were observed both at the actual spawning grounds and in the surrounding pools. During spawning, instream movement was confined to that occurring between the spawning beds and pools. On the spawning grounds grayling exhibited territorial behavior as described by Bishop (1967, 1971) and defended defined territories until spawning was complete. The downstream movement comprised of groups of 10 to 20 fish which appeared to drift slowly with the current.

A total of 122 grayling were tagged during 1979; 100 upstream and 22 downstream. Fifty-eight of the fish tagged upstream were recovered in the downstream trap. Also in 1979, 10 (4%) of the 223 grayling tagged in 1976 and 26 (67%) of the 39 grayling tagged in 1978 were recaptured. The large percentage of returns from tagging in 1978 indicate that Providence Creek grayling exhibit a strong homing behavior and that a majority of the grayling spawn annually. Recapture information on grayling tagged in 1976 and 1978 from Providence Creek is summarized in Tables 18 and 19. To date no recaptures have been reported for the 122 fish tagged in 1979.

Of the 262 grayling tagged in Providence Creek in 1976 and 1978 only five recaptures were reported from areas other than the creek (Table 20). The small sample size precluded detailed analysis of dispersal, distance travelled and rate of travel. For the five recaptures the average distance travelled was 45 km (2-72 km) and the average time at liberty was 269 days (46-440 days).

The locations of the tag returns seem to indicate that Providence Creek grayling may contribute to sport fisheries in the Fort Providence and Brabant Island areas (Fig. 8). The latter area supports an important sport fishery for grayling as described by Falk and Gillman (1974, 1980).

POPULATION ESTIMATE

The upstream count of grayling in 1979 was 467. This count is below the actual size of the spawning population since an unknown number of grayling were observed upstream of the highway crossing before the fence and trap was completed. The downstream count of 471 grayling must therefore be used as the minimum estimation of the spawning population. An estimate of the population size using the Peterson mark-recapture method was 805 grayling. From observations of the number of grayling taken by angling and other methods above the fence location and based on tag recaptures in Providence Creek and considering unaccounted tagged fish it is estimated that at least 601 to 760 grayling comprised the original spawning population. This estimate does not include juvenile grayling which were observed in the creek but were not enumerated. For comparison the spawning population of grayling was estimated to be about 1 000 in 1966 (W.A. Bond, pers. comm.).

IMPLICATIONS FOR MANAGEMENT

Providence Creek lies within a special management area of the upper Mackenzie River including all tributary streams between 116° and 118° west longitude. This management area was established for the purpose of maintaining high quality sport fisheries for Arctic grayling and northern pike (Falk and Gillman 1980). Catch and possession limits for grayling were reduced in 1974 from 10 and 10 to 5 and 10, respectively and a 356 mm (14 in) minimum size limit was imposed. The catch and possession limits for grayling were further reduced to 3 and 5, respectively, in 1980. Falk and Gillman (1980) suggest that the present regulations governing the harvest of grayling from this management area are adequate to ensure a continuing supply of large fish providing that fishing pressure does not increase dramatically.

The size and age composition as well as average growth rate suggest that Providence Creek grayling are distinct in comparison to grayling stocks in the Kakisa River and Brabant Island area. It is possible, however, that exploitation may lead to a decline in size and age of grayling in Providence Creek. Also, subsequent tag recaptures within Providence Creek provides conclusive evidence that grayling have a strong homing behavior and the majority of the population may return to the creek to spawn each year once sexual maturity is reached. Tag returns from other areas suggest that Providence Creek grayling may contribute, in part, to the sport fishery in the Brabant Island area. This is likely not the case for the Kakisa River where no tagged fish are known to have been recaptured from 1976 to 1981 (Falk et al. 1980, Moshenko and Low, pers. comm.). Protection of the spawning population of grayling in Providence Creek may be a sound management strategy especially if it can be substantiated that the stock augments recruitment of grayling to sport fisheries in the management area of the Mackenzie River.

Adult grayling utilize Providence Creek during the early spring solely for spawning purposes. The spawning period is short being less than two weeks in duration. Grayling enter the creek as soon as ice-free passages permit upstream movement and leave shortly after spawning. During this period grayling may be subjected to heavy angling pressure. Also, because Providence Creek is small and the water is fairly clear grayling are visible to the angler. However, they are generally not vulnerable to angling using legal methods since mature grayling do not feed during spawning (Bishop 1967, 1971). Further, the disturbance of the stream bed by such "fishermen" wading in the creek causes harassment of spawning fish and disruption of fertilized eggs. In short, Providence Creek does not support a "true" sport fishery. It does, however, support a spawning population of grayling which may contribute to the sport fisheries in the Mackenzie River - specifically the Fort Providence and Brabant Island areas. The fishery should therefore be managed by protecting the spawning stocks.

Christie (1978) provides a good analysis of area (or stream) closures to protect spawning stocks of fish. He states that "Technically, the time of year a fish is caught has little to do with the perpetuation of the stock to which it belongs. For example, the capture of a female fish represents exactly the same loss to the annual spawn deposition whether it occurs immediately before spawning, or many months before." The same argument may be used for area closures which in some cases may completely protect some stocks from exploitation. Further, there is considerable justification for distributing harvest moderately across all sub-stocks of species, rather than risking elimination of some of the sub-stocks (Christie 1978). This rationale may be applied directly to the special management area of the Mackenzie River with a closure on Providence Creek during the spawning period serving to distribute fishing effort across different sub-stocks of grayling.

The available spawning habitat for grayling in Providence Creek was observed to be limited in relation to the potential spawning habitat. Numerous abandoned beaver dams and deadfall upstream from the highway crossing impinge upon spawning habitat and prevent upstream movement of spawners. Removal of deadfall and beaver dams and the subsequent washing-out of accumulated organic material may enhance the spawning habitat in Providence Creek. This action may result in an increase in the number of spawners as well as egg to fry survival and may serve to augment recruitment to sport fisheries in the Mackenzie River.

RECOMMENDATIONS

1. Providence Creek should be closed to angling for the month of May to provide protection for spawning Arctic grayling.

2. A follow-up investigation should be carried out by 1985 to assess the effectiveness of the closure on Providence Creek.

3. Efforts should be made to determine removal of the possible effects of the numerous beaver dams and deadfall in

Providence Creek. This may increase the extent of spawning habitat for grayling and may result in increased recruitment of grayling to sport fisheries in the Mackenzie River.

Note: As a result of evidence indicating disturbances to the spawning substrate and harassment of the spawning grayling by anglers, the Department of Fisheries and Oceans, closed Providence Creek to angling, for the period 15 April to 30 May, effective 1981, under the Northwest Territories Fishery Regulations.

ACKNOWLEDGMENTS

The authors thank G. Carder, L. Dahlke, F. Hnytka, and R. Mulders who provided assistance in the field. Fishery Officers J. Caudron and N. Robinson based in Hay River provided logistic support. Special thanks are extended to Department of Transport - Canadian Coast Guard for their hospitality. C. Read determined the scale age of Arctic grayling and D. Glowacki typed the final report. W. Bond, K. Chang-Kue and R. Moshenko reviewed the manuscript and provided useful suggestions.

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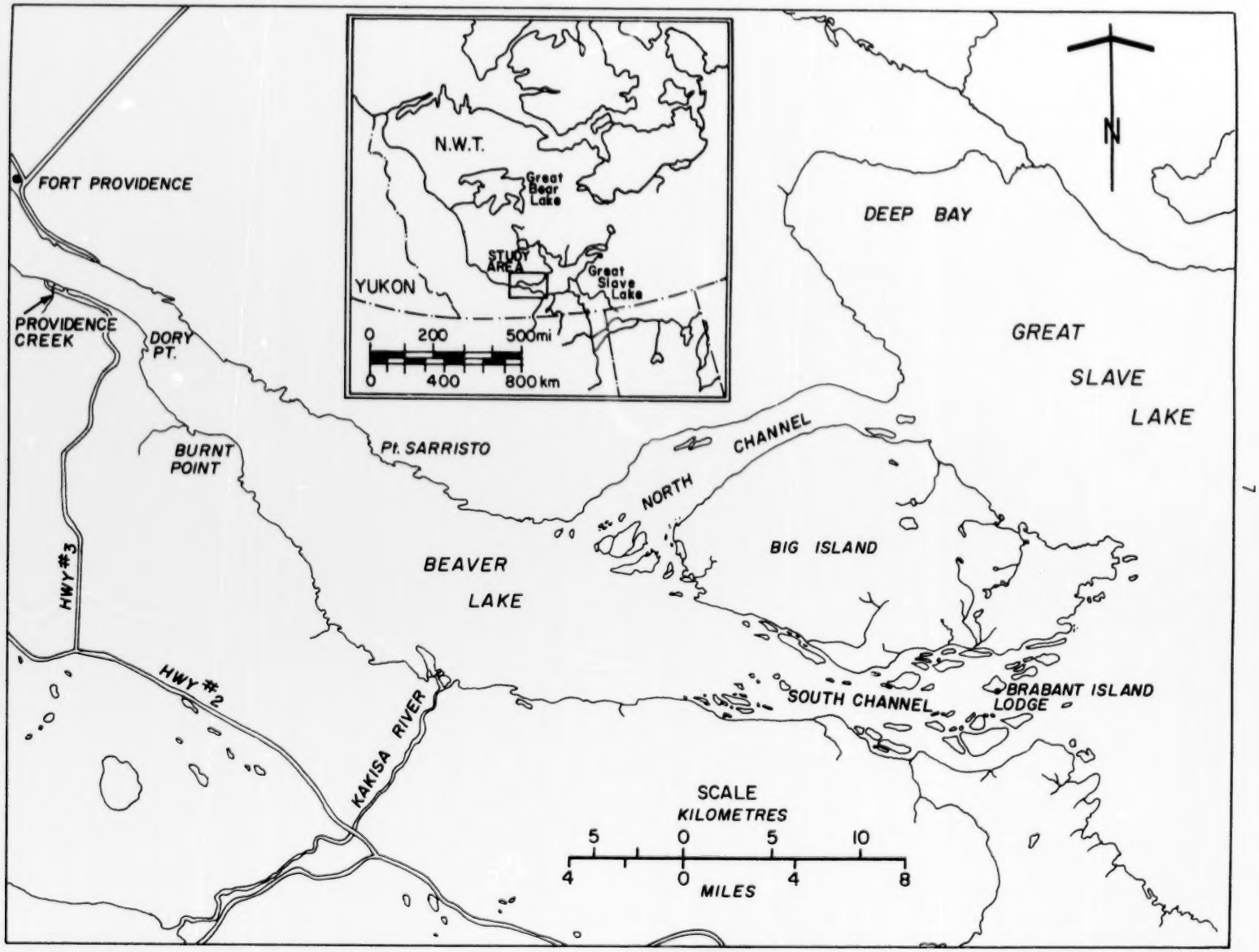

Figure 1. Map of the upper Mackenzie River area showing the location of Providence Creek.

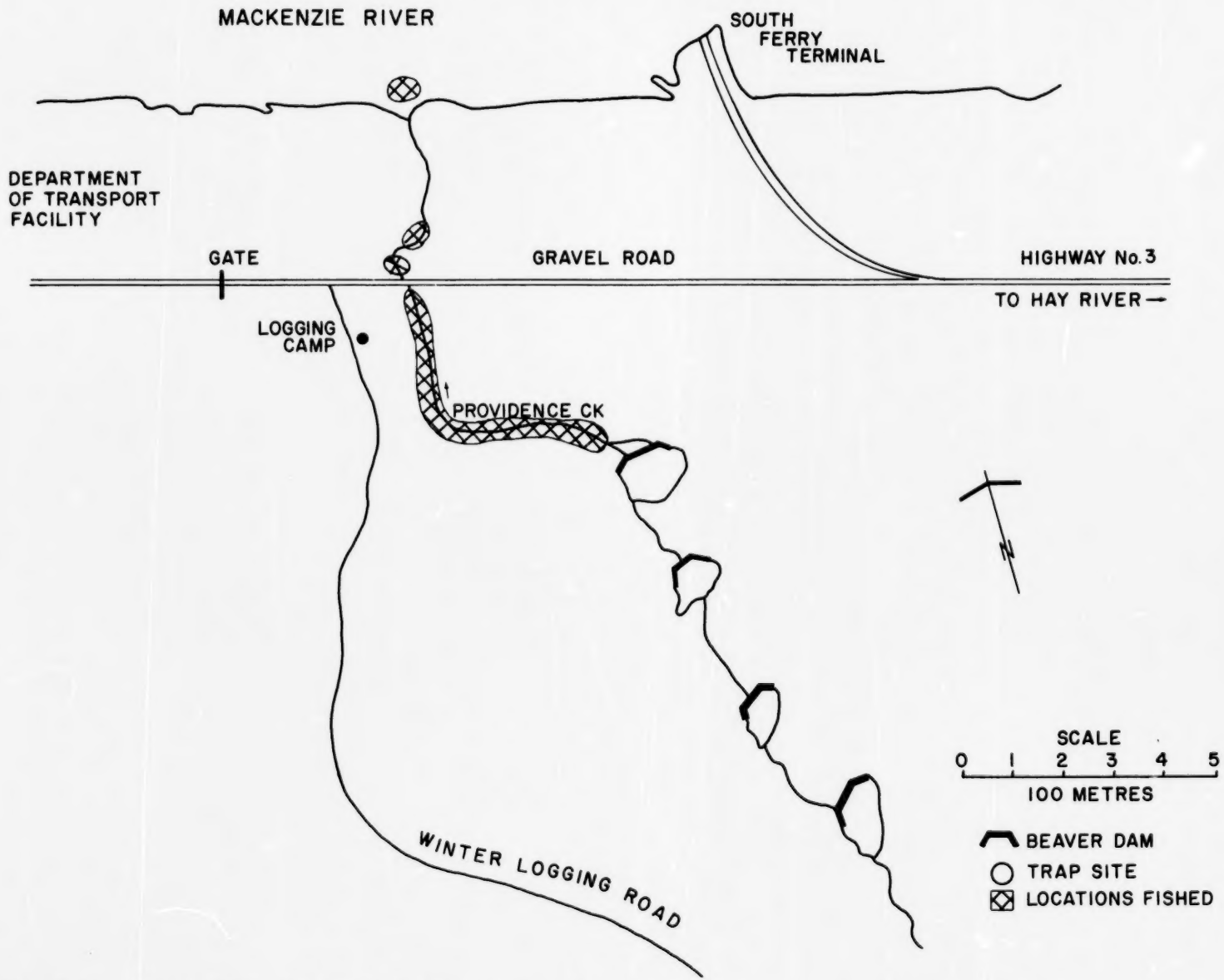

Figure 2. Map of Providence Creek showing the fish fence location and the areas fished.

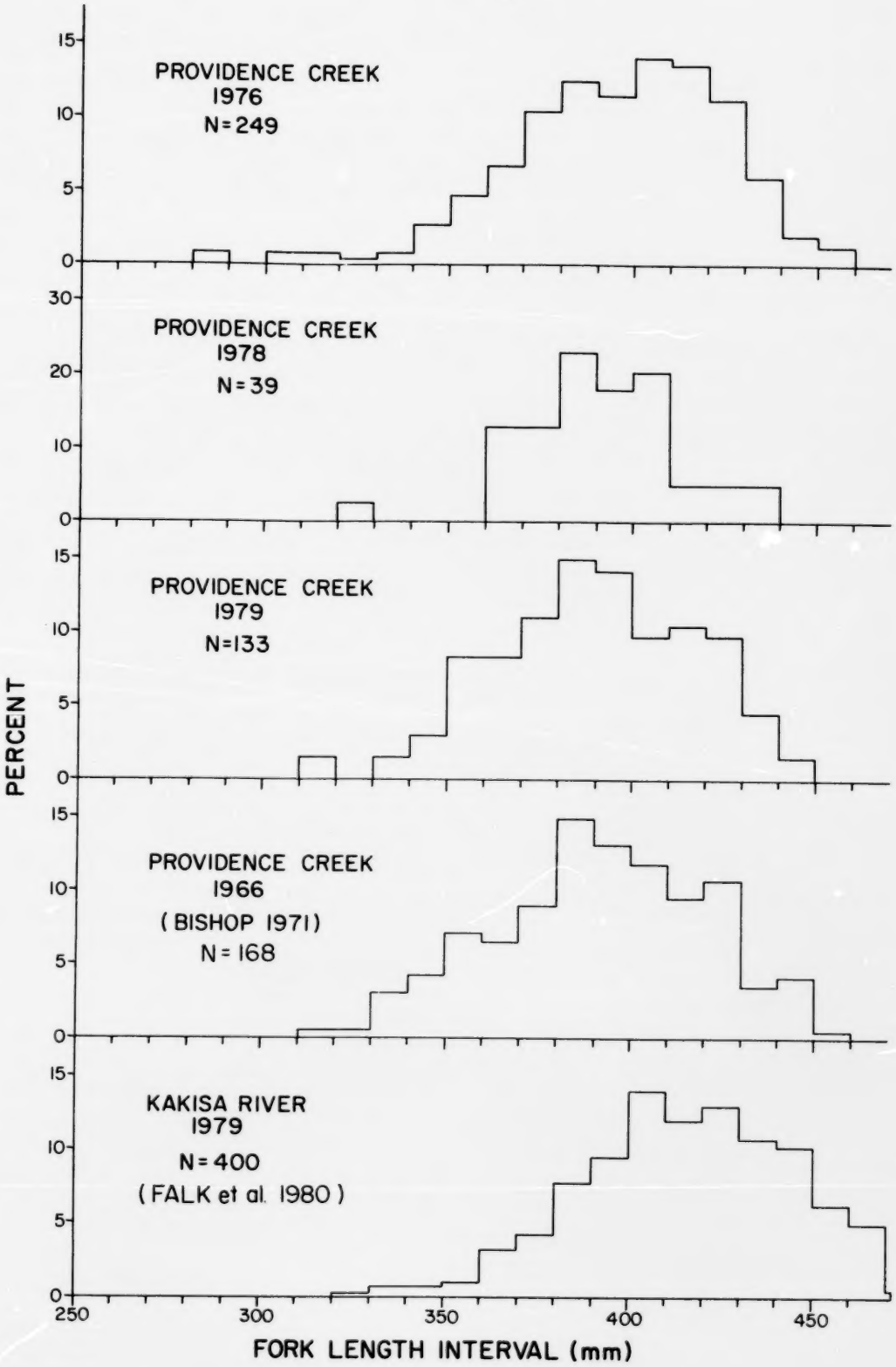

Figure 3. Length-frequency distributions for Arctic grayling from Providence Creek, 1976-79.

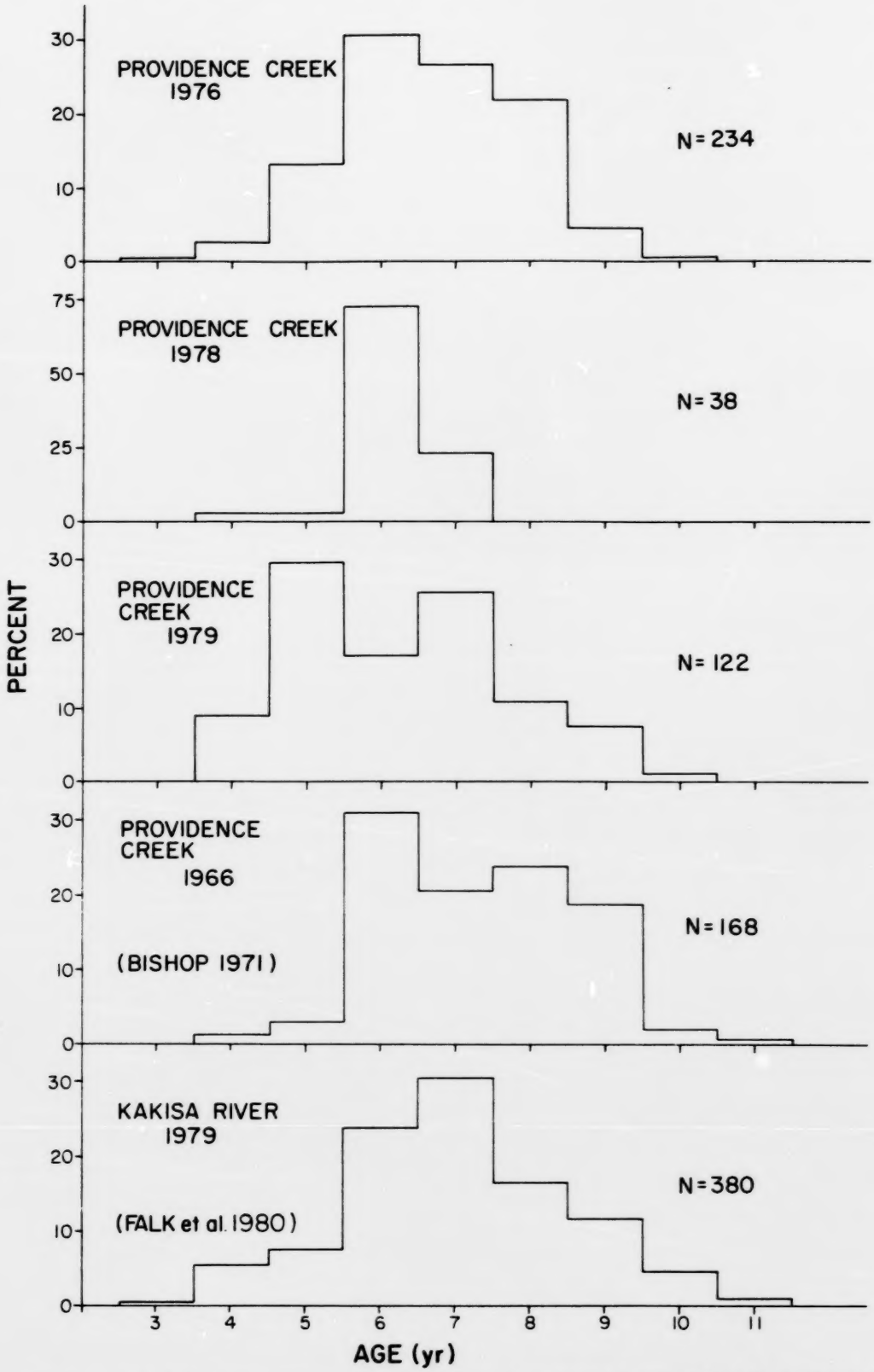

Figure 4. Age-frequency distributions for Arctic grayling from Providence Creek, 1976-79.

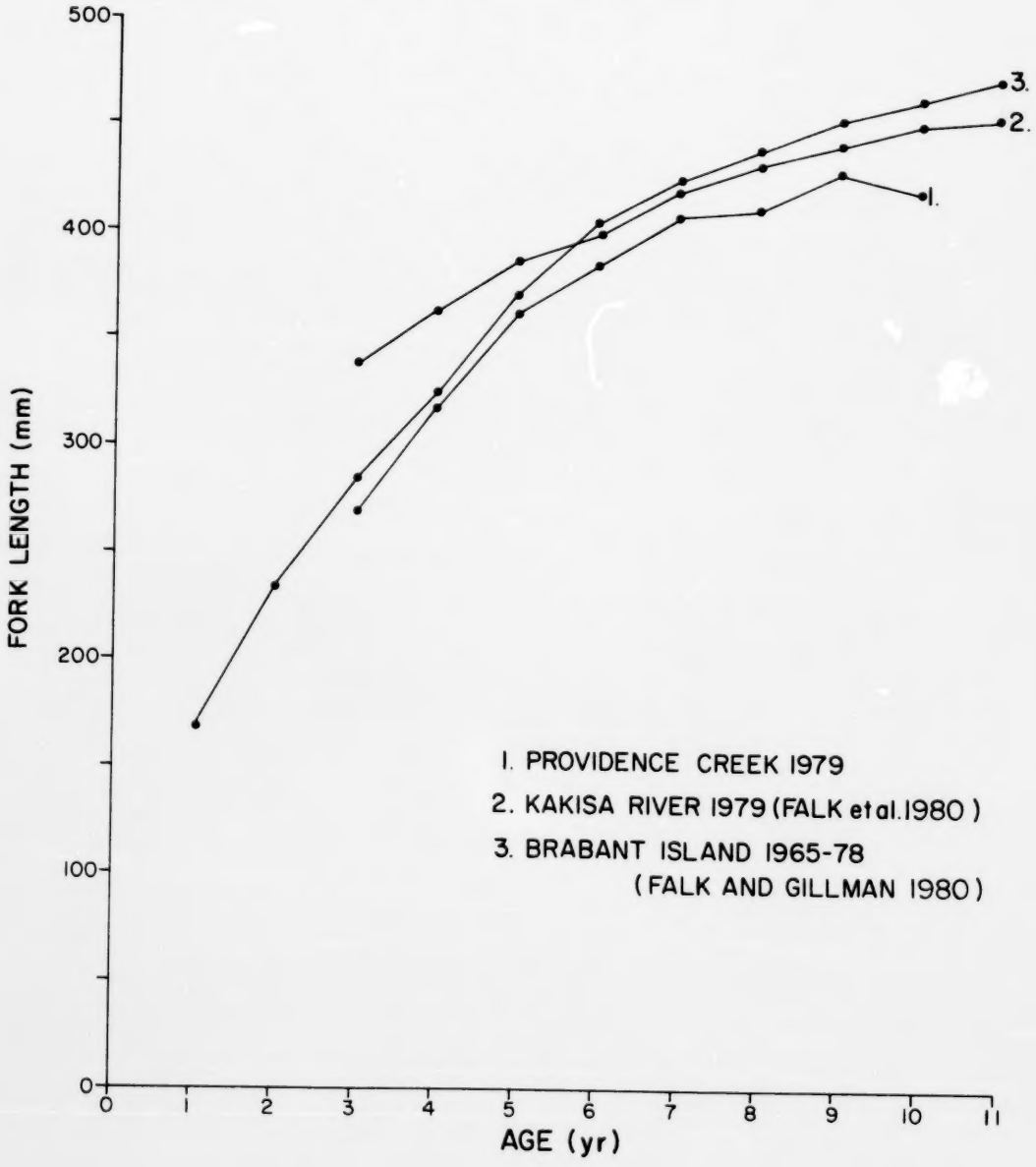

Figure 5. Comparison of age-length relationships for Arctic grayling from Providence Creek to the Kakisa River and the Brabant Island area.

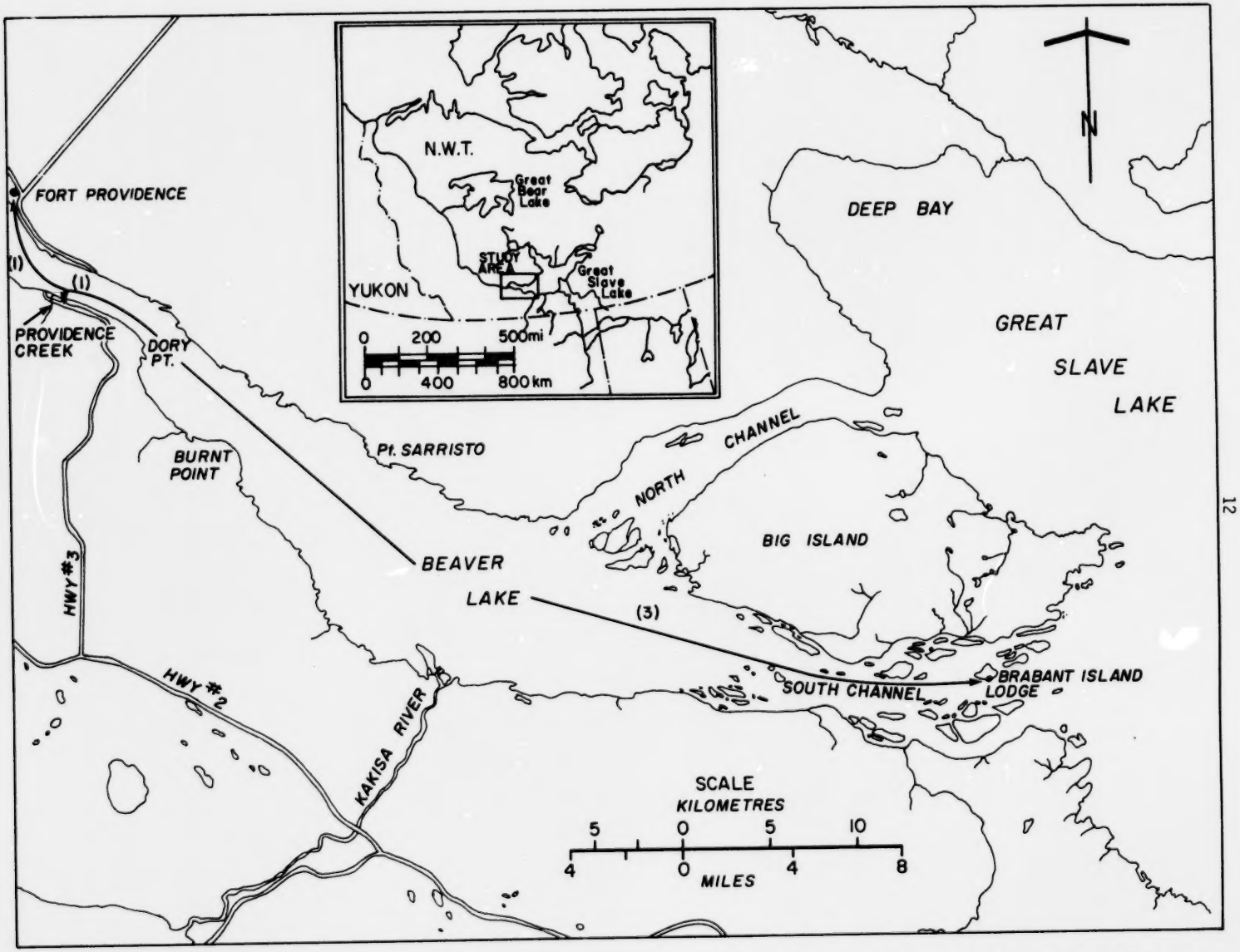

Figure 6. Daily counts (upstream and downstream) of migrant Arctic grayling in Providence Creek in relation to maximum and minimum water temperatures, 1979.

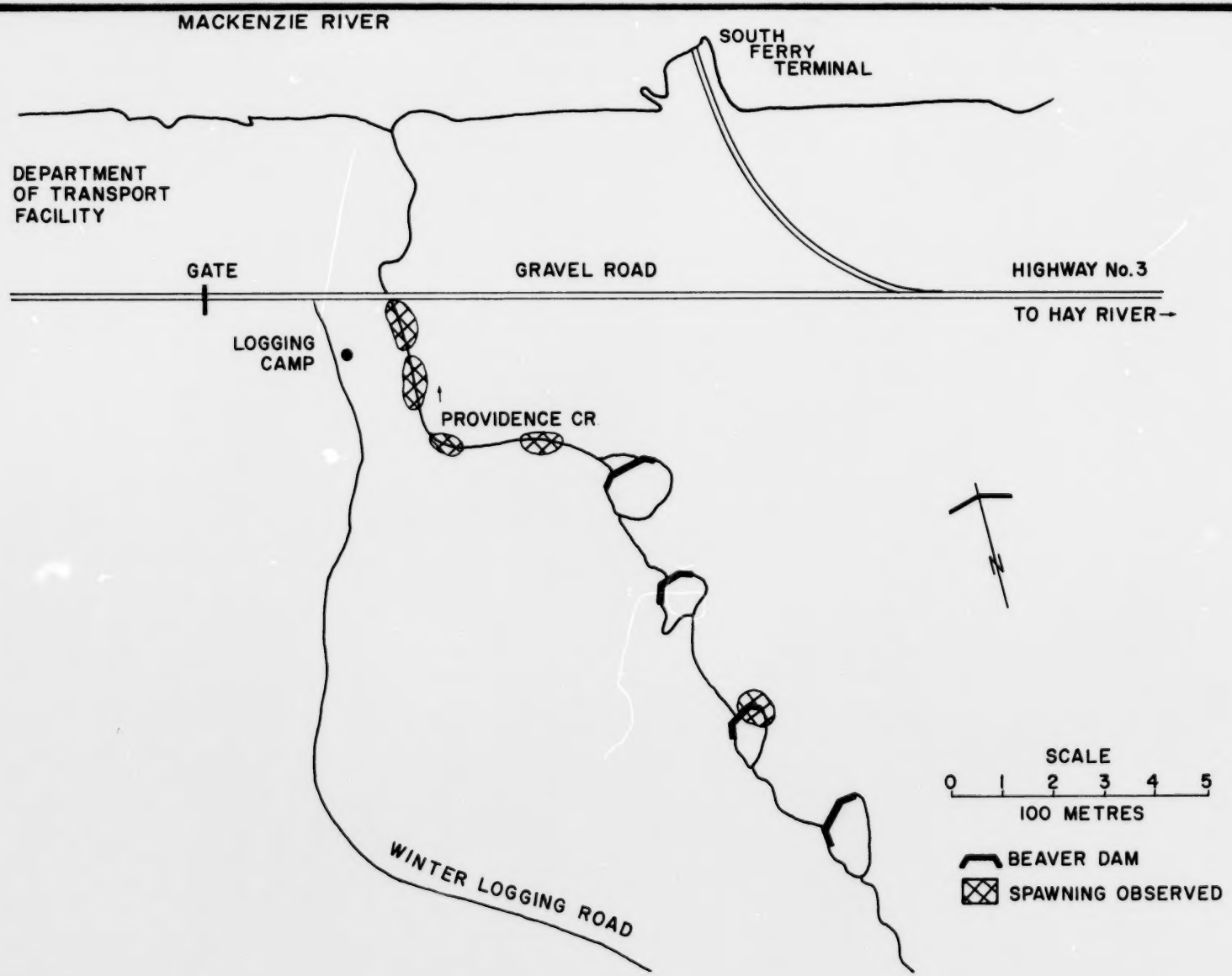

Figure 7. Map of Providence Creek showing the spawning areas observed for Arctic grayling, 1979.

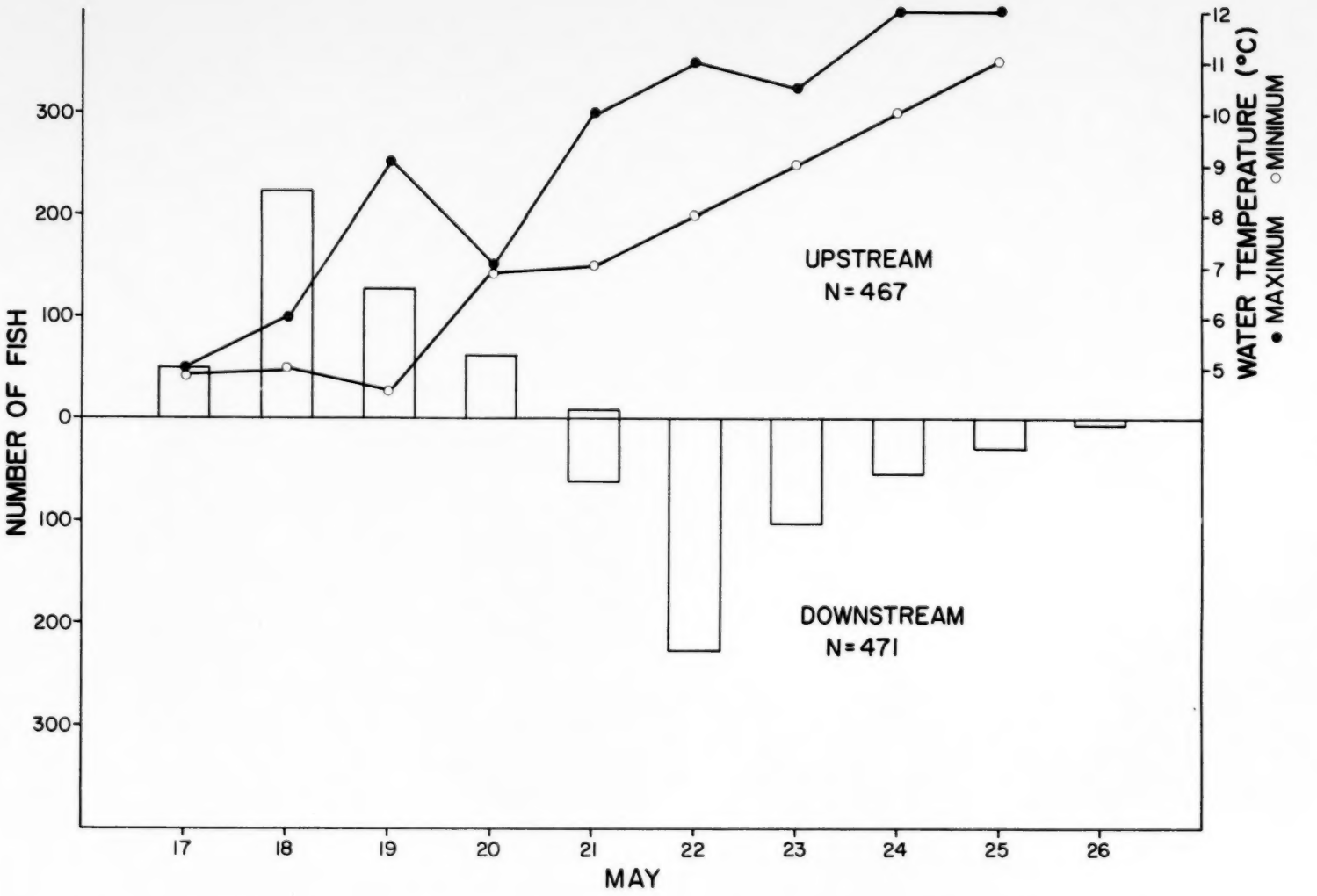

Figure 8. Distribution of Arctic grayling tagged in Providence Creek and recaptured in the Mackenzie River, 1976-79.

Table 1. Biological data by length interval for tagged Arctic grayling from Providence Creek, 1976.

Length Interval (mm)	Males							Females							Combined						F/M Ratio	No. Unknown
	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	
300-309	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	304	5.0	375	0.0	1.34	-	-	2
310-319	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	316	0.7	350	0.0	1.12	-	-	2
320-329	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	323	-	425	-	1.26	-	-	1
330-339	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	337	2.8	525	35.4	1.37	-	-	2
340-349	1	348	-	500	-	1.19	100.0	-	-	-	-	-	-	-	7	345	3.9	514	45.3	1.25	-	-	6
350-359	2	357	1.4	525	35.4	1.15	100.0	2	353	3.5	600	35.4	1.37	100.0	11	355	2.7	573	70.2	1.28	-	1.00	7
360-369	3	364	1.5	642	14.4	1.33	100.0	4	363	3.7	619	102.8	1.30	100.0	17	363	3.1	622	57.9	1.30	-	1.25	10
370-379	6	374	3.3	683	90.4	1.31	100.0	4	374	2.9	744	42.7	1.37	100.0	24	374	2.6	699	60.5	1.34	-	0.07	14
380-389	6	384	2.0	704	69.7	1.25	100.0	13	385	3.0	779	71.3	1.39	100.0	31	384	2.7	761	67.3	1.34	-	0.46	12
390-399	10	394	2.3	760	119.7	1.25	100.0	14	394	3.0	852	65.4	1.38	100.0	27	394	2.7	806	98.9	1.32	-	1.40	3
400-409	9	404	3.4	861	94.5	1.31	100.0	15	404	3.3	910	87.5	1.31	100.0	34	405	3.0	894	95.8	1.35	-	1.67	10
410-419	3	413	2.9	883	38.2	1.25	100.0	18	414	3.2	929	119.2	1.32	100.0	32	414	3.2	908	102.3	1.28	-	6.00	11
420-429	8	423	2.4	919	66.5	1.21	100.0	14	423	2.7	1001	98.8	1.32	100.0	27	423	2.6	959	101.0	1.27	-	1.75	5
430-439	2	432	0.0	1025	35.4	1.27	100.0	8	435	2.9	1084	35.2	1.32	100.0	13	434	2.9	1054	62.0	1.29	-	0.25	3
440-449	3	443	3.1	1008	62.9	1.16	100.0	2	441	0.7	1200	70.7	1.40	100.0	5	442	2.5	1085	119.4	1.26	100.0	0.67	-
450-459	2	453	3.5	1025	0.0	1.11	100.0	-	-	-	-	-	-	-	3	452	2.7	1158	230.9	1.26	-	-	1
Total	55						100.0	94						100.0	238						-	1.71	89
Mean		400	25.4	805	153.8	1.25			404	20.7	896	149.3	1.35			395	28.1	813	179.9	1.31			

Table 2. Biological data by length interval for dead-sampled Arctic grayling from Providence Creek, 1976.

Length Interval (mm)	Males							Females							Combined						F/M Ratio	No. Unknown
	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	
270-279	1	270	-	210	-	1.07	0.0	-	-	-	-	-	-	-	1	270	-	210	-	1.07	0.0	-	-
370-379	-	-	-	-	-	-	-	2	372	2.1	725	35.4	1.41	100.0	2	372	2.1	725	35.4	1.41	100.0	-	-
390-399	-	-	-	-	-	-	-	1	390	-	800	-	1.35	100.0	2	392	2.1	788	17.7	1.31	-	-	1
400-409	-	-	-	-	-	-	-	1	409	-	725	-	1.06	100.0	1	409	-	725	-	1.06	100.0	-	-
410-419	1	410	-	825	-	1.20	100.0	1	415	-	975	-	1.36	100.0	2	413	3.5	900	106.1	1.28	-	1.00	-
420-429	-	-	-	-	-	-	-	1	429	-	925	-	1.17	100.0	1	429	-	925	-	1.17	-	-	-
430-439	-	-	-	-	-	-	-	1	432	-	925	-	1.15	100.0	2	434	2.1	975	70.7	1.20	-	-	1
Total	2						50.0	7						100.0	11						-	3.50	2
Mean		340	99.0	518	435	1.13			403	25.3	829	111.3	1.27			393	46.6	785	218.5	1.25			

Table 3. Biological data by length interval for tagged and dead-sampled Arctic grayling from Providence Creek, 1976.

Length Interval (mm)	Males N	Males Length(mm) Mean	Males Length(mm) SD	Males Weight(g) Mean	Males Weight(g) SD	Males K	Males % Mat.	Females N	Females Length(mm) Mean	Females Length(mm) SD	Females Weight(g) Mean	Females Weight(g) SD	Females K	Females % Mat.	Combined N	Combined Length(mm) Mean	Combined Length(mm) SD	Combined Weight(g) Mean	Combined Weight(g) SD	Combined K	Combined % Mat.	F/M Ratio	No. Unknown
270-279	1	270	-	210	-	1.07	0.0	-	-	-	-	-	-	-	1	270	-	210	-	1.07	0.0	-	-
300-309	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	304	5.0	375	0.0	1.34	-	-	2
310-319	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	316	0.7	350	0.0	1.11	-	-	2
320-329	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	323	-	425	-	1.26	-	-	1
330-339	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	337	2.8	525	35.4	1.37	-	-	2
340-349	1	348	-	500	-	1.19	100.0	-	-	-	-	-	-	-	7	345	3.9	514	45.3	1.25	-	-	6
350-359	2	357	1.4	525	35.4	1.15	100.0	2	353	3.5	600	35.4	1.37	100.0	11	355	2.7	573	70.2	1.28	-	1.00	7
360-369	3	364	1.5	642	14.4	1.33	100.0	4	363	3.7	619	102.8	1.30	100.0	17	363	3.1	622	57.9	1.30	-	1.25	10
370-379	6	374	3.3	683	90.4	1.31	100.0	6	373	2.8	738	37.9	1.42	100.0	26	374	2.6	701	58.9	1.34	-	1.00	14
380-389	6	384	2.0	704	69.7	1.25	100.0	13	385	3.0	779	71.3	1.37	100.0	31	384	2.7	761	67.3	1.34	-	2.17	12
390-399	10	394	2.3	760	119.7	1.24	100.0	15	394	3.1	848	64.4	1.39	100.0	29	394	2.7	804	95.5	1.32	-	1.50	4
400-409	9	404	3.4	861	94.5	1.31	100.0	16	405	3.4	898	96.4	1.36	100.0	35	405	3.1	889	98.6	1.34	-	1.78	10
410-419	4	413	2.9	869	42.7	1.24	100.0	19	414	3.2	932	116.3	1.32	100.0	34	414	3.2	907	100.9	1.30	-	4.75	11
420-429	8	423	2.4	919	66.5	1.21	100.0	15	423	3.0	997	97.2	1.31	100.0	28	424	2.8	958	99.3	1.26	-	1.88	5
430-439	2	432	0.0	1025	35.4	1.27	100.0	9	434	2.8	1067	62.5	1.30	100.0	15	434	2.8	1043	66.5	1.28	-	4.50	4
440-449	3	443	3.1	1008	62.9	1.16	100.0	2	441	0.7	1200	70.7	1.40	100.0	5	442	2.5	1085	119.4	1.26	-	0.67	-
450-459	2	452	3.5	1025	0.0	1.11	100.0	-	-	-	-	-	-	-	3	452	2.7	1158	230.9	1.26	-	-	1
Total	57						98.0	101						100.0	249						-	1.77	91
Mean		398	30.3	795	170.4	1.25			404	20.9	891	147.6	1.35			395	29.0	812	181.4	1.30			

Table 4. Biological data by length interval for tagged Arctic grayling from Providence Creek, 1978.

Length Interval (mm)	Males N	Males Length(mm) Mean	Males Length(mm) SD	Males % Mat.	Females N	Females Length(mm) Mean	Females Length(mm) SD	Females % Mat.	Combined N	Combined Length(mm) Mean	Combined Length(mm) SD	Combined % Mat.	F/M Ratio	No. Unknown
320-329	-	-	-	-	1	325	-	100.0	1	325	-	100.0	-	-
360-369	1	365	-	100.0	2	365	3.5	100.0	4	365	2.1	-	2.0	1
370-379	-	-	-	-	2	375	3.5	100.0	4	377	3.0	-	-	2
380-389	1	385	-	100.0	5	384	2.9	100.0	9	384	2.7	-	5.0	3
390-399	3	394	3.6	100.0	3	393	1.0	100.0	7	394	2.6	-	1.0	1
400-409	5	404	2.8	100.0	-	-	-	-	8	404	2.9	-	-	3
410-419	1	416	-	100.0	1	418	-	100.0	2	417	1.4	100.0	1.0	-
420-429	1	424	-	100.0	-	-	-	-	2	426	2.1	-	-	1
430-439	2	431	1.4	100.0	-	-	-	-	2	431	1.4	100.0	-	-
Total	14			100.0	14			100.0	39			-	1.00	11
Mean		404	18.1			380	20.8			382	21.1			

Table 5. Biological data by length interval for tagged Arctic grayling from Providence Creek, 1979.

Length Interval (mm)	Males N	Males Length(mm) Mean	Males Length(mm) SD	Males Weight(g) Mean	Males Weight(g) SD	Males K	Females N	Females Length(mm) Mean	Females Length(mm) SD	Females Weight(g) Mean	Females Weight(g) SD	Females K	Combined N	Combined Length(mm) Mean	Combined Length(mm) SD	Combined Weight(g) Mean	Combined Weight(g) SD	Combined K	No. Unknown
310-319	-	-	-	-	-	-	-	-	-	-	-	-	2	315	0.0	513	17.7	1.64	2
330-339	-	-	-	-	-	-	-	-	-	-	-	-	2	336	1.4	575	35.4	1.52	2
340-349	-	-	-	-	-	-	-	-	-	-	-	-	4	345	0.8	650	54.0	1.58	4
350-359	-	-	-	-	-	-	-	-	-	-	-	-	11	353	3.2	711	62.6	1.61	11
360-369	-	-	-	-	-	-	-	-	-	-	-	-	11	363	3.1	759	55.1	1.58	11
370-379	-	-	-	-	-	-	-	-	-	-	-	-	16	376	3.0	855	61.4	1.61	16
380-389	-	-	-	-	-	-	1	388	-	900	-	1.54	20	386	2.2	871	88.2	1.52	19
390-399	-	-	-	-	-	-	1	397	-	1075	-	1.72	19	393	2.9	954	91.8	1.57	18
400-409	-	-	-	-	-	-	-	-	-	-	-	-	13	405	3.4	983	93.8	1.48	13
410-419	-	-	-	-	-	-	-	-	-	-	-	-	14	415	2.7	1057	109.4	1.48	14
420-429	-	-	-	-	-	-	-	-	-	-	-	-	13	425	3.0	1160	146.3	1.51	13
430-439	-	-	-	-	-	-	-	-	-	-	-	-	6	436	3.1	1192	166.3	1.44	6
440-449	-	-	-	-	-	-	-	-	-	-	-	-	2	443	4.2	1200	315.4	1.38	2
Total	-						2						133						131
Mean	-	-	-	-	-	-		393	6.4	988	123.7	1.63		390	27.3	920	185.0	1.54	

Table 6. Length-weight relationship summary, $\log_{10}W = a + b\ (\log_{10}L)$, for tagged Arctic grayling from Providence Creek, 1976-79.

Year	Sex	N	Y-intercept (a)	Slope (b)	Standard Deviation of b (S_b)	95% C.I. of b
1976	Males	55	-4.1405	2.706	0.229	2.247 - 3.165
	Females	94	-4.2253	2.752	0.202	2.351 - 3.153
	Combined	238	-4.7169	2.935	0.095	2.749 - 3.121
1979	Combined	133	-3.6948	2.568	0.115	2.343 - 2.793

Table 7. Biological data by age group for tagged Arctic grayling from Providence Creek, 1976.

Age (Yr)	Males N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Females N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Combined N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	F/M Ratio	No. Unknown
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	317	14.2	392	49.2	1.23	-	-	6
5	6	371	11.5	650	103.7	1.26	100.0	2	368	17.7	650	35.4	1.31	100.0	31	362	14.6	615	92.6	1.29	-	0.33	23
6	21	385	16.9	731	114.3	1.27	100.0	19	388	18.7	805	145.7	1.37	100.0	69	384	17.3	752	125.0	1.32	-	0.90	29
7	12	411	20.6	831	165.9	1.19	100.0	31	407	19.9	904	152.5	1.33	100.0	57	408	19.7	869	149.6	1.28	-	2.58	14
8	6	412	17.4	913	56.5	1.32	100.0	29	411	14.6	947	103.9	1.37	100.0	49	413	14.6	946	120.3	1.35	-	4.83	14
9	5	438	17.9	960	80.2	1.15	100.0	4	422	14.4	1106	126.5	1.47	100.0	10	429	17.0	1008	128.6	1.28	-	0.80	1
10	1	421	-	1000	-	1.34	100.0	-	-	-	-	-	-	-	1	421	-	1000	-	1.34	100.0	-	-
Total	51						100.0	85						100.0	223						-	1.67	87
Mean	6.7[a]	399	25.7	794	151.5	1.25		7.2[a]	404	20.6	900	152.8	1.36		6.7[a]	394	28.2	808	183.0	1.31			

[a]Indicates mean age.

Table 8. Biological data by age group for dead-sampled Arctic grayling from Providence Creek, 1976.

Age (Yr)	Males N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Females N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Combined N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	F/M Ratio	No. Unknown
3	1	270	-	210	-	1.07	0.0	-	-	-	-	-	-	-	1	270	-	210	-	1.07	0.0	-	-
6	-	-	-	-	-	-	-	2	372	2.1	725	35.4	1.41	100.0	2	372	2.1	725	35.4	1.41	100.0	-	-
7	-	-	-	-	-	-	-	5	415	16.9	870	103.7	1.22	100.0	5	415	16.9	870	103.7	1.22	100.0	-	-
8	1	410	-	825	-	1.20	100.0	-	-	-	-	-	-	-	2	402	12.0	800	35.4	1.24	-	-	1
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	435	-	1025	-	1.25	-	-	1
Total	2						50.0	7						100.0	11						-	3.50	2
Mean	5.5[a]	340	99.0	518	434.9	1.13		6.7[a]	403	25.3	829	111.3	1.27		6.8[a]	393	46.6	785	218.5	1.25			

[a]Indicates mean age.

Table 9. Biological data by age group for tagged and dead-sampled Arctic grayling from Providence Creek, 1976.

Age (Yr)	Males N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Females N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	Combined N	Length(mm) Mean	SD	Weight(g) Mean	SD	K	% Mat.	F/M Ratio	No. Unknown
3	1	270	-	210	-	1.07	0.0	-	-	-	-	-	-	-	1	270	-	210	-	1.07	0.0	-	-
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	317	14.2	392	49.2	1.23	-	-	6
5	6	371	11.5	650	103.7	1.26	100.0	2	368	17.7	650	35.4	1.31	100.0	31	362	14.6	615	92.6	1.29	-	0.33	23
6	21	385	16.9	730	114.3	1.28	100.0	21	386	18.4	798	140.5	1.37	100.0	71	384	17.2	751	123.3	1.32	-	1.00	29
7	12	411	20.6	831	165.9	1.19	100.0	36	408	19.5	899	146.0	1.32	100.0	62	408	19.4	869	145.7	1.27	-	3.00	14
8	7	411	15.9	900	61.2	1.30	100.0	29	411	14.6	947	103.9	1.37	100.0	51	412	14.6	941	121.5	1.34	-	4.14	15
9	5	438	17.9	960	80.2	1.15	100.0	4	422	14.4	1106	126.5	1.47	100.0	11	430	16.2	1009	122.1	1.28	-	0.80	2
10	1	421	-	1000	-	1.34	100.0	-	-	-	-	-	-	-	1	421	-	1000	-	1.34	100.0	-	-
Total	53						98.0	92						100.0	234						-	1.74	89
Mean	6.7[a]	396	30.8	784	169.0	1.24		7.1[a]	404	20.8	895	150.7	1.35		6.7[a]	394	29.2	807	184.3	1.30			

[a]Indicates mean age.

Table 10. Biological data by age group for tagged Arctic grayling from Providence Creek, 1978.

Age (Yr)	Males N	Males Length(mm) Mean	Males Length(mm) SD	Males % Mat.	Females N	Females Length(mm) Mean	Females Length(mm) SD	Females % Mat.	Combined N	Combined Length(mm) Mean	Combined Length(mm) SD	Combined % Mat.	F/M Ratio	No. Unknown
4	-	-	-	-	-	325	-	100.0	1	325	-	100.0	-	-
5	-	-	-	-	-	-	-	-	1	364	-	100.0	-	1
6	9	406	15.4	100.0	10	385	15.5	100.0	27	395	17.7	100.0	1.11	8
7	5	400	23.6	100.0	2	378	6.4	100.0	9	393	20.7	100.0	0.40	2
Total	14			100.0	13			100.0	38			100.0	0.93	11
Mean	6.4[a]	404	18.1		6.0[a]	379	21.4		6.2[a]	392	21.5			

[a]Indicates mean age.

Table 11. Biological data by age group for tagged Arctic grayling from Providence Creek, 1979.

Age (Yr)	Males N	Males Length(mm) Mean	Males Length(mm) SD	Males Weight(g) Mean	Males Weight(g) SD	Males K	Females N	Females Length(mm) Mean	Females Length(mm) SD	Females Weight(g) Mean	Females Weight(g) SD	Females K	Combined N	Combined Length(mm) Mean	Combined Length(mm) SD	Combined Weight(g) Mean	Combined Weight(g) SD	Combined K	No. Unknown
4	-	-	-	-	-	-	-	-	-	-	-	-	11	344	18.1	641	99.5	1.57	11
5	-	-	-	-	-	-	-	-	-	-	-	-	36	370	14.1	789	86.7	1.56	36
6	-	-	-	-	-	-	-	-	-	-	-	-	21	392	17.0	935	121.6	1.55	21
7	-	-	-	-	-	-	2	392	6.4	988	123.7	1.63	31	405	17.0	1005	120.0	1.50	29
8	-	-	-	-	-	-	-	-	-	-	-	-	13	407	19.1	1056	178.6	1.55	13
9	-	-	-	-	-	-	-	-	-	-	-	-	9	417	11.7	1156	198.0	1.59	9
10	-	-	-	-	-	-	-	-	-	-	-	-	1	446	-	1225	-	1.38	1
Total	-					-	2						122						120
Mean	-	-	-	-	-		7.0[a]	392	6.4	988	123.7	1.63	6.3[a]	389	27.2	915	188.9	1.55	

[a]Indicates mean age.

Table 12. Comparison of the scale age of Arctic grayling from the date of tagging to the date of recapture from Providence Creek, 1976-79.

Date of Tagging	Date of Recapture	N	Age at Tagging	% Agreement	% Diff. by ±1 yr	% Diff. by ±2 yr	% Diff. by ±3 yr
April 1978	May 1979	16	-	100	0	0	0
April 1976	May 1979	1	4	100	0	0	0
		1	5	100	0	0	0
		4	6	0	50	50	0
		1	7	0	100	0	0
		2	8	0	0	50	50
		9	All	22	33.5	33.5	11

Table 13. Annual mortality rates for tagged Arctic grayling from Providence Creek, 1976-79.

Year	Sex	N	Age-classes used	Survival (S)	SE of S	Var. of S	95% C.I. of S	Annual Mortali Rate(A
1976	Males	45	6 - 10	0.49	0.05	0.003	0.39 - 0.60	0.51
	Females	64	6 - 9	0.37	0.05	0.002	0.28 - 0.47	0.63
	Combined	186	6 - 10	0.51	0.03	0.001	0.45 - 0.56	0.50
1978	Males	14	6 - 7	0.28	0.10	0.010	0.07 - 0.48	0.72
	Females	12	6 - 7	0.15	0.10	0.009	0.04 - 0.35	0.85
	Combined	36	5 - 7	0.21	0.06	0.004	0.09 - 0.33	0.80
1979	Combined	54	7 - 10	0.39	0.05	0.003	0.29 - 0.50	0.61

Table 14. Fecundity of Arctic grayling from Providence Creek, 1976.

Number	Length (mm)	Weight (g)	No. of Ova			No. Ova per Kg Body Weight
			Right	Left	Total	
1	432	925	-	-	15620	16887
2	390	800	7142	4861	12003	15004
3	415	975	-	-	9752	10002
4	373	750	5161	6224	11185	14913
5	418	1025	4480	4278	8758	8544
6	409	725	-	-	4694	6475
7	393	775	-	-	11383	14688
8	-	-	-	-	9679	-
9	-	-	-	-	15867	-
10	-	-	-	-	13349	-
Mean	404	854	5594	5121	11229	12359

Table 15. Summary of fish enumerated upstream and downstream during the spring counting fence operation on Providence Creek, 1979.

Date	Upstream			Downstream		
	Arctic grayling	Northern pike	Total	Arctic grayling	Northern pike	Total
May 17	49	33	82	0	0	0
18	222	27	249	0	0	0
19	127	7	134	0	0	0
20	62	4	66	0	0	0
21	7	0	7	61	26	87
22	0	0	0	227	7	234
23	0	0	0	102	10	112
24	0	0	0	52	3	55
25	0	0	0	27	9	36
26	0	0	0	2	0	2
Total	467	71	538	471	55	526

Table 16. Summary of diel timing of the upstream migration of Arctic grayling in Providence Creek, 1979. Fish counted at times other than those indicated were included in the next time period. (-) indicates times not checked.

Date	Time Checks 0400	1200	1600	2000	2400 hrs	No. Fish
May 17	-	-	-	12	37	49
18	132	-	56	-	34	222
19	39	24	32	-	32	127
20	-	43	-	-	19	62
21	-	7	-	-	-	7
Total	171	74	88	12	122	467

Table 17. Summary of diel timing of the downstream migration of Arctic grayling in Providence Creek, 1979. Fish counted at times other than those indicated were included in the next time period. (-) indicates times not checked.

Date	Time Checks 0400	0800	1200	1600	2000	2400 hrs.	No. Fish
May 21	-	-	-	-	-	61	61
22	77	-	150	-	-	-	227
23	-	-	-	-	42	60	102
24	-	27	-	-	-	25	52
25	-	-	-	27	-	-	27
26	2	-	-	-	-	-	2
Total	79	27	150	27	42	146	471

Table 18. Recapture information on Arctic grayling tagged in Providence Creek in 1976 and recaptured in Providence Creek from 1977 to 1979.

No.	Tagging Information				Recapture Information				Elapsed	Change(±) in		Annual Increment	
	Date (D/M/Y)	Length (mm)	Weight (g)	Age (yr)	Date (D/M/Y)	Length (mm)	Weight (g)	Age (yr)	Time (Days)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
1	29/4/76	377	700	6	17/5/78	-	-	-	753	-	-	-	-
2	29/4/76	386	750	-	22/5/79	400	850	-	1088	+14	+100	+ 5	+ 33
3	29/4/76	374	725	6	17/5/79	388	975	7	1083	+14	+250	+ 5	+ 83
4	29/4/76	362	650	6	19/5/79	411	1175	8	1085	+49	+525	+16	+175
5	29/4/76	356	700	5	17/5/79	398	1000	8	1083	+42	+300	+14	+100
6	29/4/76	415	850	7	19/5/79	423	1000	9	1085	+18	+150	+ 6	+ 50
7	29/4/76	392	650	6	12/5/77	-	-	-	379	-	-	-	-
8	29/4/76	387	750	6	-/5/77	-	-	-	≈380	-	-	-	-
9	29/4/76	316	350	4	25/4/79	395	850	7	1090	+79	+500	+26	+167
10	29/4/76	394	800	6	15/5/77	-	-	-	382	-	-	-	-
11	29/4/76	361	550	6	24/5/79	389	725	8	1090	+28	+175	+ 9	+ 58
12	29/4/76	408	1000	8	18/5/79	414	1100	9	1085	+18	+150	+ 6	+ 50
13	29/4/76	387	700	6	21/5/79	-	-	-	1087	-	-	-	-
14	29/4/76	358	500	5	17/5/79	397	700	-	1083	+39	+200	+13	+ 67
15	29/4/76	409	1025	-	12/5/77	-	-	-	379	-	-	-	-
16	29/4/76	387	775	5	15/5/77	-	-	-	382	-	-	-	-
17	29/4/76	400	925	8	17/5/78	-	-	-	753	-	-	-	-
18	30/4/76	400	975	6	15/5/77	-	-	-	382	-	-	-	-
19	30/4/76	368	650	6	22/5/79	385	850	7	1117	+17	+200	+ 6	+ 67
20	30/4/76	395	950	8	24/5/79	-	-	-	1119	-	-	-	-
21	30/4/76	409	750	8	25/5/79	417	800	8	1117	+ 8	+ 50	+ 3	+ 17
22	30/4/76	395	875	6	23/5/79	418	1075	7	1088	+23	+200	+ 8	+ 67

Table 19. Recapture information on Arctic grayling tagged in Providence Creek in 1978 and recaptured in Providence Creek during 1979.

No.	Tagging Information				Recapture Information				Elapsed	Change(±) in		Annual Increment	
	Date (D/M/Y)	Length (mm)	Weight (g)	Age (yr)	Date (D/M/Y)	Length (mm)	Weight (g)	Age (yr)	Time (Days)	Length (mm)	Weight (g)	Length (mm)	Weight (g)
1	17/5/78	427	-	6	17/5/79	421	850	7	365	- 6	-	- 6	-
2	17/5/78	394	-	6	23/5/79	398	875	9	371	+ 4	-	+ 4	-
3	17/5/78	385	-	6	17/5/79	408	1000	7	365	+23	-	+23	-
4	17/5/78	405	-	6	17/5/79	410	1025	7	365	+ 5	-	+ 5	-
5	17/5/78	430	-	7	21/5/79	-	-	-	369	-	-	-	-
6	17/5/78	418	-	6	17/5/79	430	1050	-	365	+22	-	+22	-
7	17/5/78	405	-	6	19/5/79	442	1300	7	367	+37	-	+37	-
8	17/5/78	-	-	-	22/5/79	385	850	7	366	-	-	-	-
9	17/5/78	401	-	6	22/5/79	-	-	-	374	-	-	-	-
10	17/5/78	383	-	6	18/5/79	391	875	7	366	+ 7	-	+ 7	-
11	17/5/78	400	-	6	21/5/79	-	-	-	369	-	-	-	-
12	17/5/78	395	-	7	20/5/79	-	-	-	368	-	-	-	-
13	17/5/78	338	-	6	20/5/79	-	-	7	368	-	-	-	-
14	17/5/78	402	-	7	17/5/79	414	925	8	365	+12	-	+12	-
15	17/5/78	385	-	6	17/5/79	416	1000	7	365	+31	-	+31	-
16	17/5/78	397	-	6	23/5/79	422	1050	7	371	+25	-	+25	-
17	17/5/78	367	-	6	19/5/79	379	925	7	367	+12	-	+12	-
18	17/5/78	372	-	7	19/5/79	378	900	8	367	+ 6	-	+ 6	-
19	17/5/78	-	-	-	23/5/79	409	875	8	371	-	-	-	-
20	17/5/78	392	-	-	19/5/79	405	1125	8	367	+13	-	+13	-
21	17/5/78	405	-	6	24/5/79	410	1025	7	372	+ 5	-	+ 5	-
22	17/5/78	388	-	6	25/5/79	400	850	7	371	+12	-	+12	-

Table 20. Information on Arctic grayling tagged in Providence Creek and recaptured in other areas, 1976-79.

No.	Tagging Information				Recapture Information			
	Date (D/M/Y)	Length (mm)	Weight (g)	Age (yr)	Location	Date (D/M/Y)	Elapsed Time (Days)	Distance (km)
1	24/4/76	403	875	8	Fort Providence	14/6/76	46	13
2	29/4/76	413	1100	7	Brabant Is.	23/8/76	116	69
3	30/4/76	380	875	7	Lobstick Is.	13/7/77	409	72
4	29/4/76	407	1050	8	Wrigley Harbour	-/8/77	≈440	69
5	17/5/78	378	-	6	Providence Ferry	17/4/79	335	2

Appendix 1. A description of the fish fence installed in Providence Creek in 1979 to enumerate and tag Arctic grayling.

The fence component consisted of 4 wings in a "X" configuration with a central trap positioned in the middle of the creek. Wings were constructed of two materials; 1) wooden frame panels (4 m x 1.5 m) overlaid with welded wire mesh (2.5 cm x 2.5 cm); or 2) hollow aluminum poles (2.5 cm x 2 m) placed vertically within 3 m x 1.5 m wooden panels at 2 cm intervals. Panels were wired to and supported by snow fence stakes which were driven into the creek bed. To ensure complete blockage of fish movement under the fence a 1 m width of poultry wire was attached to the bottom edge of the wings and anchored in place with sandbags.

The trap (1.3 m x 2.6 m x 1.7 m) was of woodframe construction overlaid with 2.5 cm x 2.5 cm wire fabric. Roof and floor sections were 1.9 cm plywood. Entrances to the trap were formed by two door panels set at a 45^{o} angle to provide a vertical opening approximately 6 cm wide. Doors were opened or closed as required to allow fish to collect within the trap. Both the trap and the fence were cleaned of debris and inspected for openings daily.

Appendix 2. A description of the relative stages of maturity used for nothern fish in 1972-78 and 1979.

1972 - 78[a]				1979[a]			
Sex F	Sex M	Maturity stage		Maturity stage	Female	Male	
1	6	Immature	- virgin fish, gonad thin and threadlike, often incomplete	Immature	1 - ovaries granular in texture, up to full length in body cavity, hard and triangular in shape, firm membrane; eggs distinguishable	6 -	testes puttylike firmness, tubular and scalloped in shape, long and thin, and may be full length in body cavity
2	7	Maturing	- virgin or non-virgin fish not spawning in current year, gonad full length, firm, eggs of small size, gonads partially filling body cavity	Mature	2 - current year's spawner; ovaries fill body cavity; eggs nearing full size but not loose	7 -	current year's spawner; testes large and lobate; white-purplish in colour; milt not expelled by pressure
3	8	Mature	- fish spawning in current year, gonad full size filling body cavity, eggs prominent, full size	Ripe	3 - ovaries greatly extended, fill body cavity; eggs full size; eggs expelled by slight pressure	8 -	testes full size; white and lobate; milt expelled by slight pressure
4	9	Ripe	- mature fish in spawning condition, eggs translucent, milt or eggs expelled under slight pressure	Spent	4 - spawning complete; ovaries flaccid; seed eggs apparent; presence of residual mature eggs	9 -	testes flaccid with some milt, blood vessels obvious with pink-violet coloration
5	10	Spent	- mature fish completed spawning, gonads, collapsed with ruptured blood vessels prominent.	Resting	5 - non-virgin; not spawning in current year	10 -	non-virgin; not spawning in current year

[a] Fish of unknown sex were coded as 0.

Appendix 3. Daily water and air temperatures recorded at Providence Creek, 1979.

Date	Water Temperature(°C)			Air Temperature(°C)		
	Max.	Min.	Mean	Max.	Min.	Mean
May 17	5.0	5.0	5.0	22	11	17
18	6.0	5.0	5.5	18	11	15
19	9.0	4.5	7.0	22	1	12
20	7.0	7.0	7.0	-	6	-
21	10.0	7.0	8.7	-	-	-
22	11.0	8.0	9.8	-	-	-
23	10.5	9.0	9.8	-	-	-
24	12.0	10.0	11.0	-	-	-
25	12.0	11.0	11.7	5	21	13

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